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Title:	Applied ML Needs in Uncrewed Aerial Systems
Author(s):	Schultz-Fellenz, Emily S.
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Applied ML Needs in Uncrewed Aerial Systems

LANL Mission Space Overview
UAS … Uncrewed Aerial Systems
UAS … Unveiling Anthropogenic Signatures
UAS … Uniting to Attack Science

Emily S. Schultz-Fellenz
Los Alamos National Laboratory
Earth and Environmental Sciences Division
3 Feb 2022
AI4Opt

We have an **urgent need** to **optimize data analyses and UAS operations** to better position its use in sensitive and high-consequence national security applications.

NNSS

SNL

LANL has a **mature, robust, and multidisciplinary UAS deployment capability** with proficiency in single and multi-modal data acquisition for signature detection.






LANL UAS Team Workforce

Emily Schultz-Fellenz

UAS Team Capability Lead

Underground Explosion Signatures SME

Staff Scientist

Adam Collins*

UAS Flight Logistics Lead

Vegetation Signatures SME

Research Technologist

Damien Milazzo*

UAS Flight Operations Lead

Radiation Signatures SME

Research Technologist

Erika Swanson

UAS Mission Planning Lead

Geologic Signatures SME

Staff Scientist

Brandon Crawford

UAS Flight Support

Geomorphic Change Detection SME

Research Technologist

James Lee

UAS Flight Support

Multispectral & Gas Sensing SME

Staff Scientist

Dane Coats*

UAS Flight Support

Data Analysis and ML SME

Graduate Research Assistant

Aaron Anderson*

UAS Flight Support

Chemical Signatures SME

Staff Scientist

Brad Yoakam*

UAS Flight Support

Chemical Signatures SME

Research Technologist

Eric Guiltinan*

UAS Flight Support

Carbon and H_2 Capture & Storage SME

Staff Scientist

Richard Pratt

UAS Flight Support

Geospatial Analysis SME

Post-Masters Student

Earth and Environmental Sciences Division // **Chemistry Division**

*Current FAA Part 107 Certified sUAS Pilot

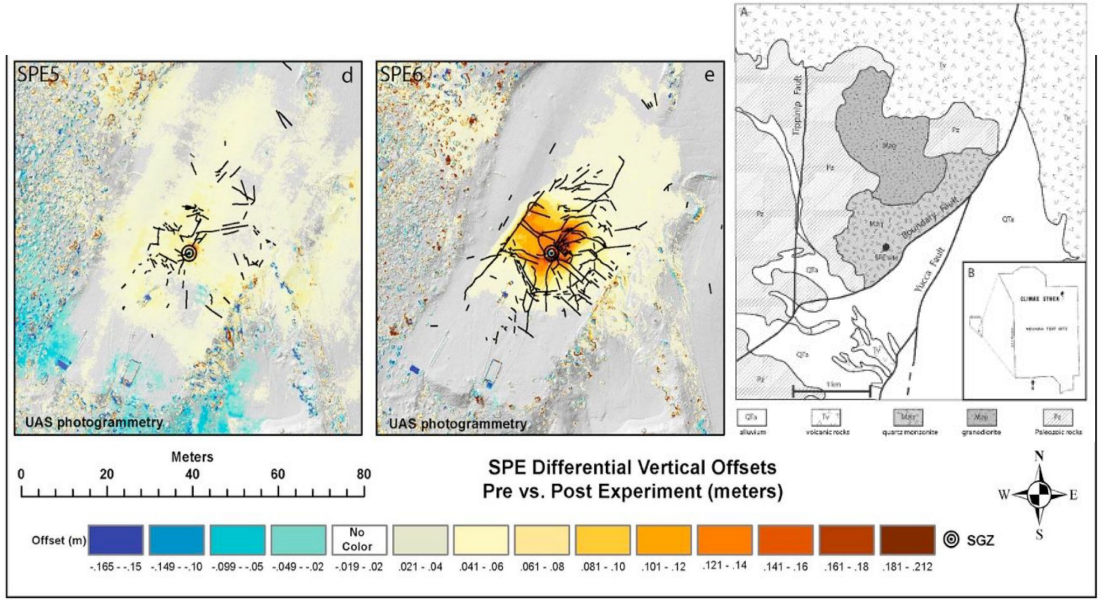
We **want** tools that can:

- Apply domain knowledge to automate national security-relevant signature detection and discrimination in
  - complex natural environments
  - spatio-temporal regime
  - engineered environments
- Help improve access to flight telemetry information
- Realize risk-aware efficiency in surveillance flight missions
- Drive us drive towards real-time signature detection (links to flight operational efficiency)
- Be easily used and integrated by rock jocks/veg heads/field folks

…and collaborators to develop/refine/test these tools in operational environments

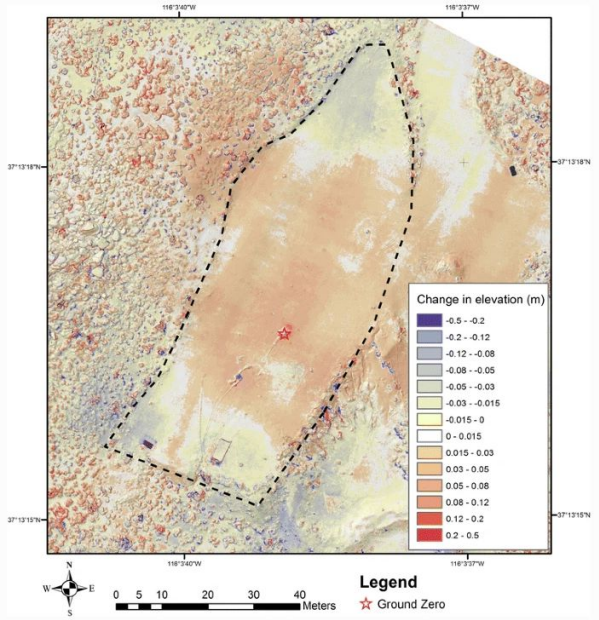
We use state-of-practice computer vision (SfM) for image processing, but we **do not have reliable ML tools to perform explosion-related change detection**.

https://www.energy.gov/nnsa/articles/nnsa-conducts-sixth-source-physics-experiment-advance-nuclear

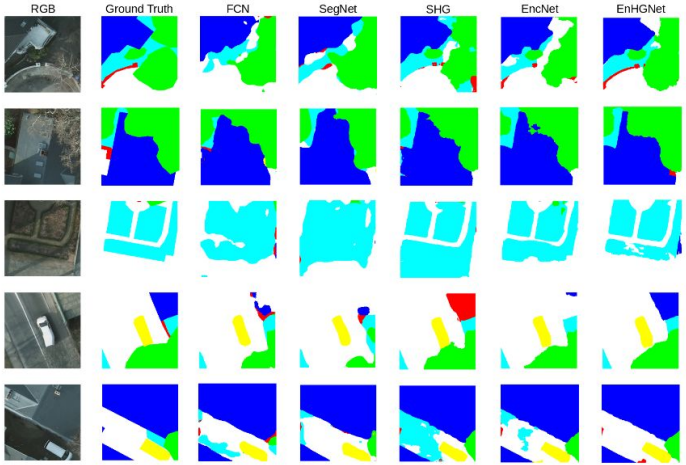


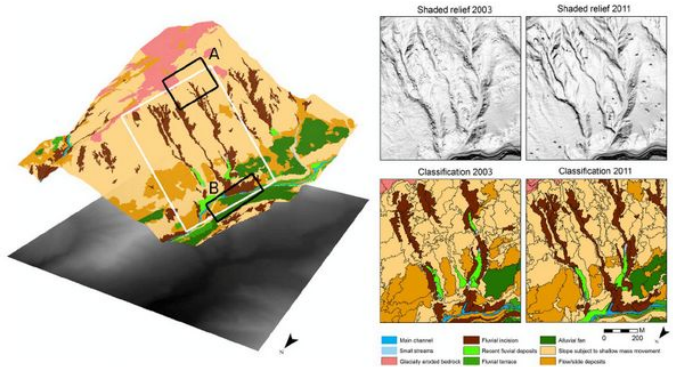
Schultz-Fellenz et al., 2020

ML tools have **difficulty discriminating explosion-relevant** signatures.



Schultz-Fellenz et al., 2018
SfM multi-temporal surface changes from underground explosions

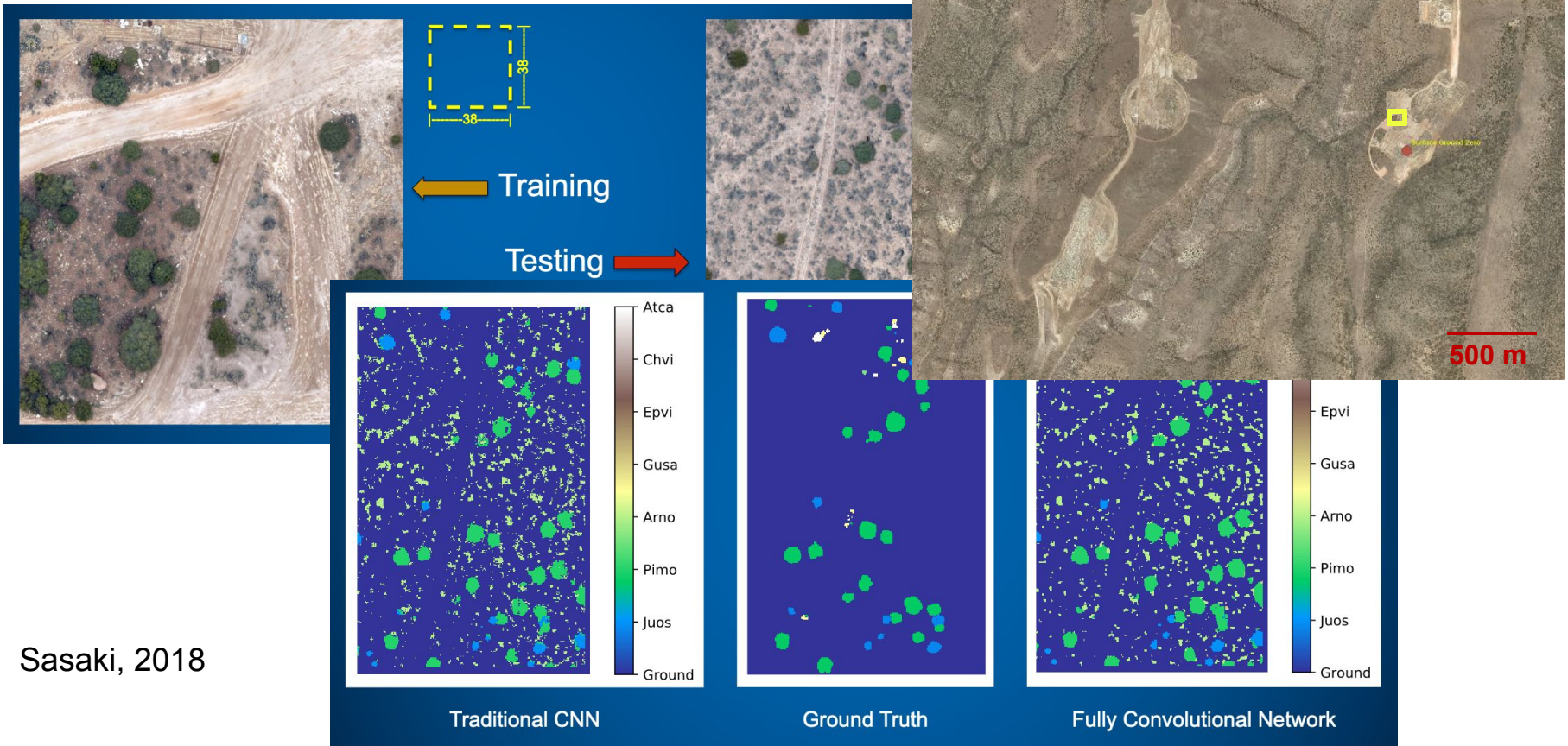




Li et al., 2018
Stacked encoder-decoder improves multi-scale feature detection, but focuses on built infrastructure; needs improvement to detect fine natural features and image changes that have limited to no textural variability.

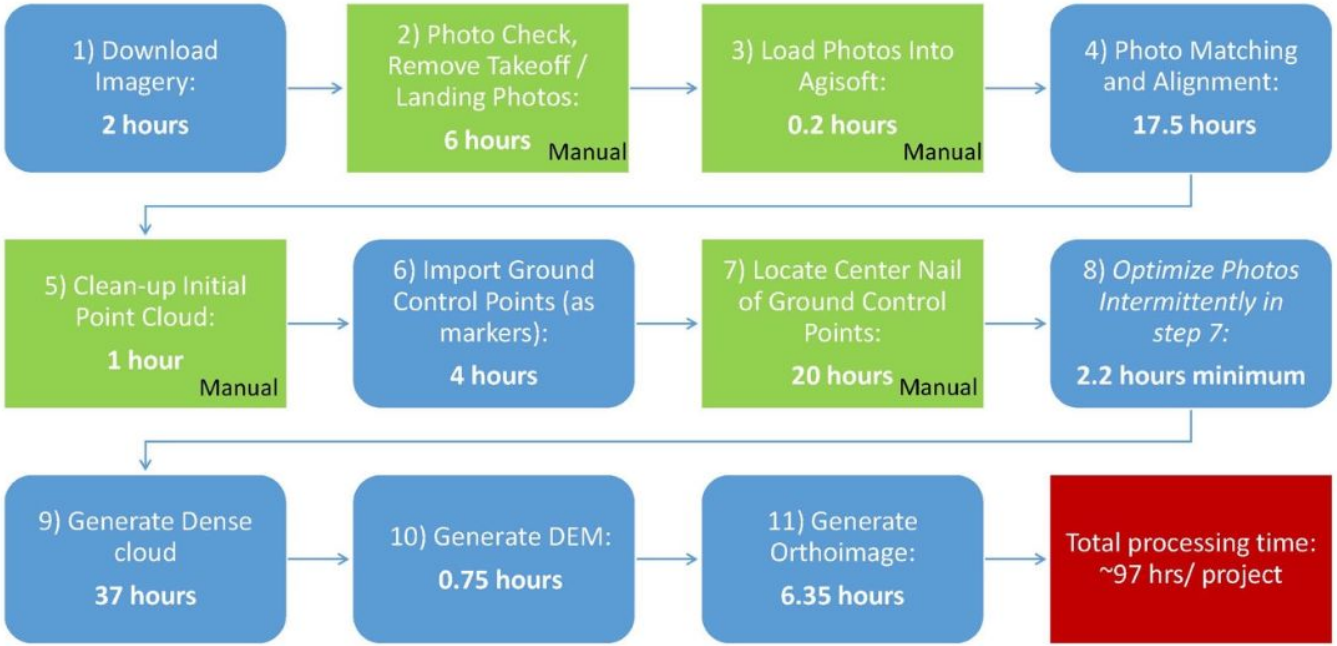
Anders et al., 2013
Object-based, multi-temporal feature extraction can find volumetric change, but changes ID'ed are 2 orders of magnitude larger than explosion signatures.

ML tools falter in performing **relevant pattern recognition and in spatial upscaling**.



Sasaki, 2018

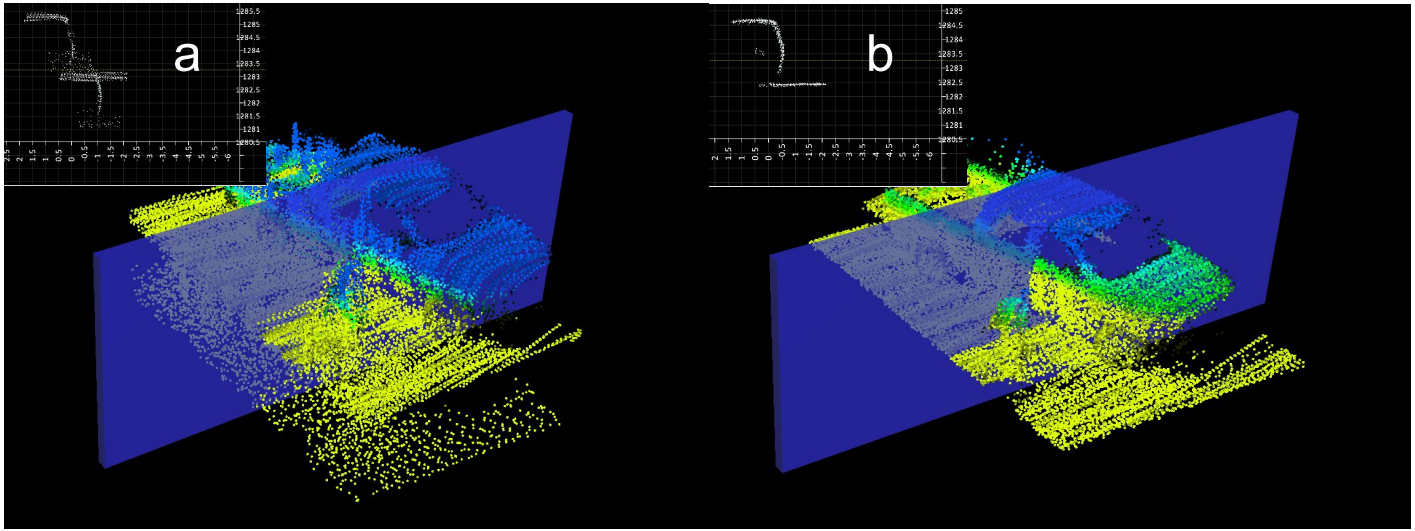
We measure our SfM data processing time in weeks, including many manual steps, when customers need completed, automated processing in *hours or minutes*.



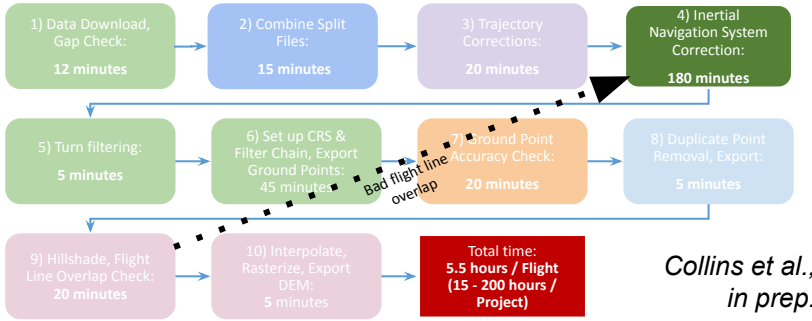
Crawford et al., 2021
Sponsor: NA-22 Defense Nuclear Nonproliferation

ML tools to perform **accurate, rapid data alignment** help with locating and interpreting signatures

Woodbury et al., 1999

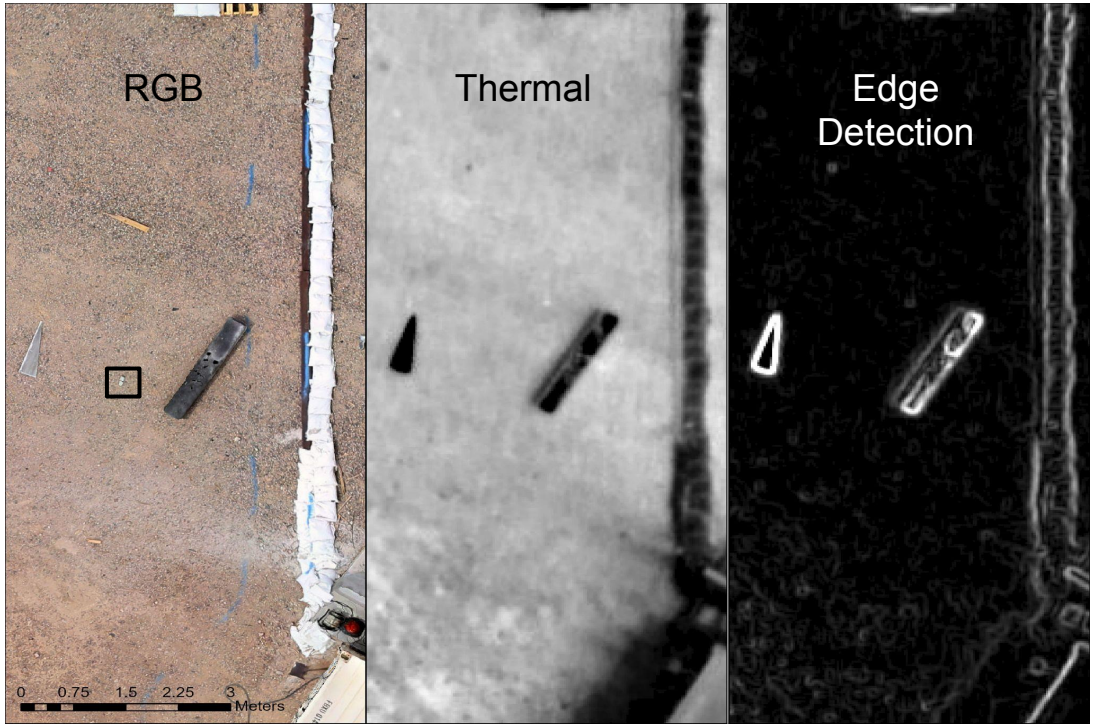


Using ML to accelerate accurate lidar data alignment helps to **quickly identify and constrain spatial extent** of anthropogenic signatures, which aids **interpretation of formation mechanisms**.

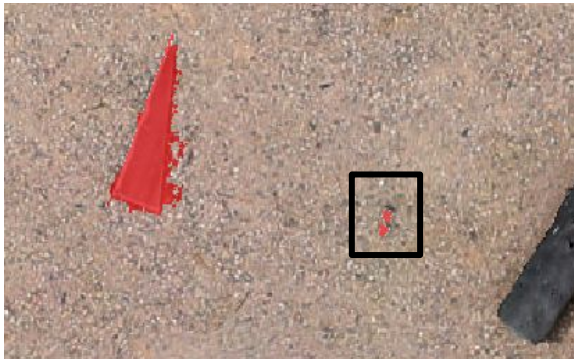


Collins et al., in prep.

SVM and Random Forest classification can detect **subpixel scale signatures within noisy data.**



Segmented Image

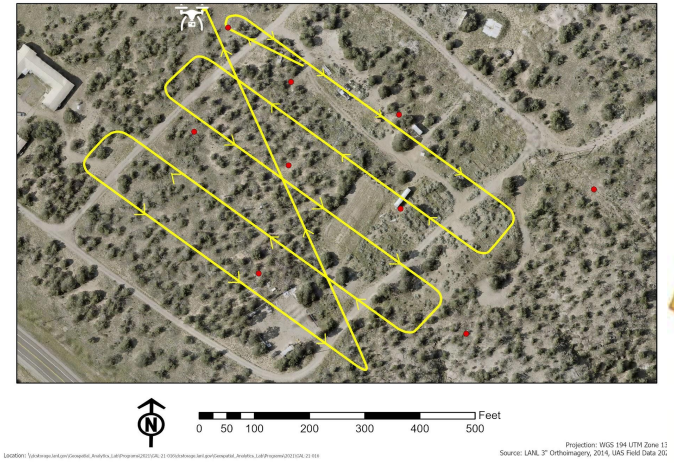


Random Forest classification

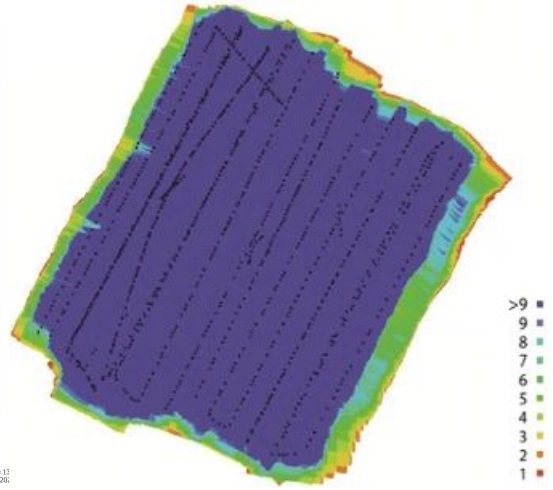
ML processing of COTS optical and thermal data shows promise in enabling **rapid, subpixel scale fragment detection and fragment material characterization.**

Crawford et al., in prep.

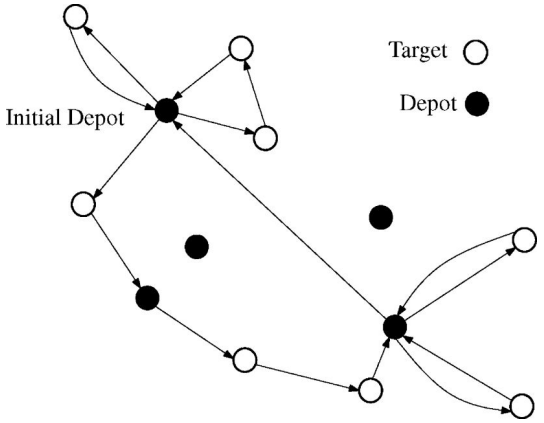
Can our field data collections become **time- and/or signature-detection-optimized**?



Webster et al., 2021



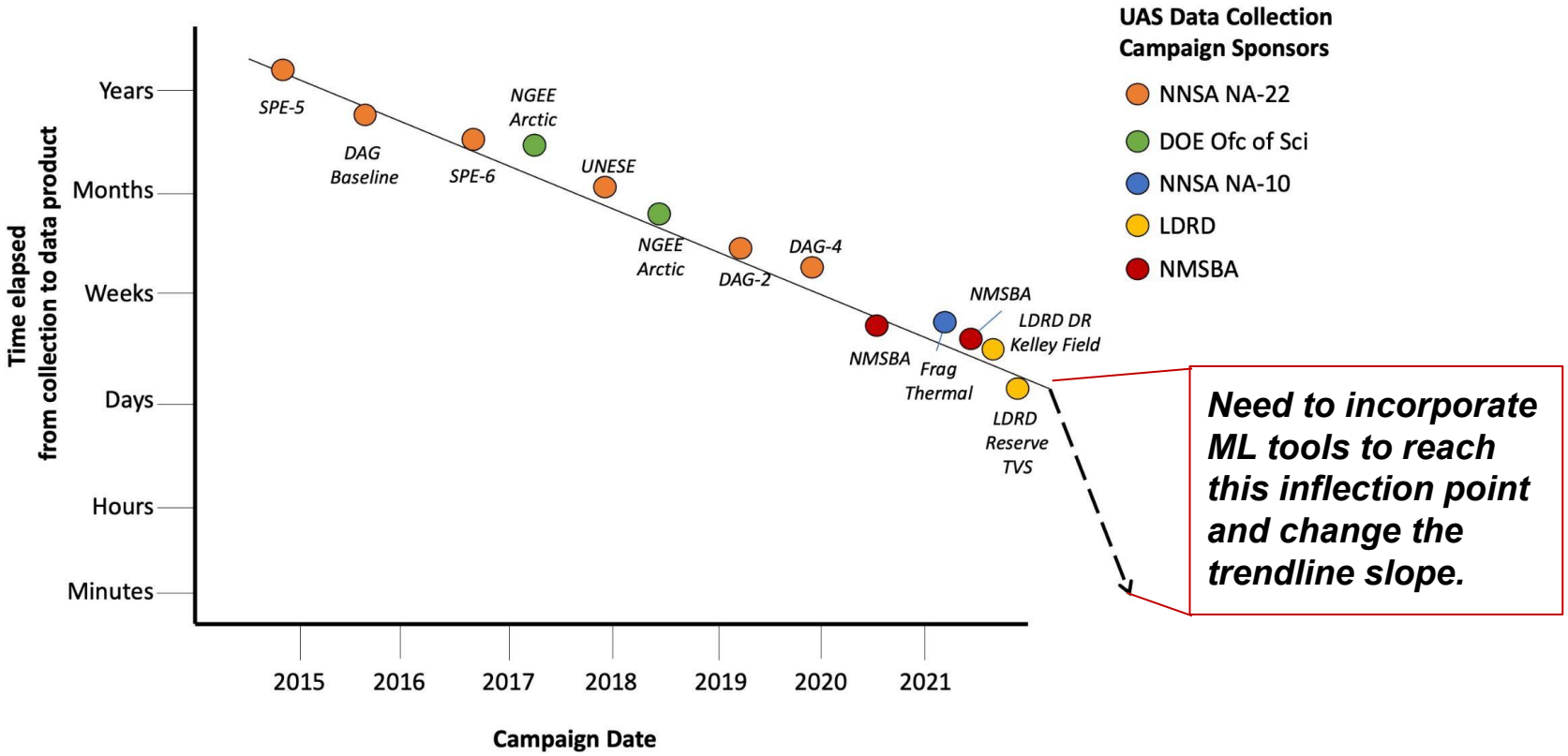
Schultz-Fellenz et al., 2018



Sundar and Rathinam, 2014

Constrained Learning optimization of mission planning could **shorten** deployment time and **maximize** battery use.
Robust Learning optimization could **permit near-realtime target detection.**
We have not yet tested available ML tools in an operational environment.

While our **data processing efficiency has improved** through time…



ML tools can, and do, provide implementable solutions to optimize data collection and analysis and get accurate results faster.

How and where can you help us to develop or implement ML tools in our mission planning, analyses, and data interpretation?

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Thank You!